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THE CALCULATED EFFECT OF VARIOUS HYDRODYNAMIC AND AERODYNAMIC FACTORS ON THE TAKE-OFF OF A LARGE FLYING BOAT

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SUMMARY

An investigation was made of the influence of various factors on the take-off performance of a hypothetical large flying boat by means of take-off calculations. The factors varied in the calculations were size of hull (load coefficient), wing setting, trim, deflection of flap, wing loading, aspect ratio, and parasite drag.

The take-off times and distances were calculated to the stalling speeds and the performance above these speeds was separately studied to determine piloting technique for optimum take-off. It was found, for the flying boat investigated, that:

(1) The final selection of the load coefficient, within a fairly large range of values, could be based on considerations other than the calculated take-off performance.

(2) The angle of wing setting giving the minimum total resistance at 85 percent of the stalling speed is still a good compromise wing setting. The use of flaps in take-off tends to reduce the loss in performance obtained with a low angle of wing setting.

(3) Deviations of more than 1½° above or 1° below the trim for minimum water resistance result in large increases in the time and the distance of the take-off. A method of determining a precision take-off giving the optimum performance is suggested.

(4) The net effect of the flaps was to improve the take-off performance, which becomes more important as the wing loading increases. There is little advantage in using deflections of the flaps much greater than 15°. A method of improving the take-off performance by using a delayed deflection of the flaps is suggested.

(5) With high wing loadings, the resistance at high speeds becomes increasingly important. High angles of wing setting, wings of high aspect ratios, low parasite drag, and the use of flaps improve the calculated take-off performance.

INTRODUCTION

Present designs for large flying boats are characterized by high wing loading, high aspect ratio, and low parasite drag. The high wing loadings result in the universal use of flaps for reducing the take-off and landing speeds. These factors affect take-off performance and influence to a certain extent the design of the hull.

The purpose of the investigation described in this paper is to evaluate the importance of various design factors that influence the take-off performance of a large hypothetical flying boat representative of present design practice. Some of the factors have been studied in earlier investigations but not in connection with the aerodynamic and the hydrodynamic characteristics now of interest, such as wings with small areas and high aspect ratios, low parasite drag, high length-beam ratio for the hull, and high loadings of the hull.

PROCEDURE AND CALCULATIONS

The factors studied in the investigation are as follows:

1. Size of hull (load coefficient).
2. Wing setting.
3. Trim.
4. Deflection of flap.
5. Wing loading.
6. Wing aspect ratio.
7. Parasite drag.

The effect of variation in these factors on net accelerating force and take-off performance was calculated for a hypothetical flying boat having the following basic characteristics:

Gross load (lb)	100, 000
Wing (NACA 3–10–18):	
Root section	NACA 23018
Tip section	NACA 23009
Taper ratio	3
Total horsepower at take-off (four engines)	6,000
Propeller:	
Diameter (ft)	14
Number of blades	3
Type	Constant speed, Bureau of Aeronautics No. 5868–9
Flaps:	
Type	Split
Location	Half on each side of center line of flying boat
Span, percent wing span	60.0
Chord, percent wing chord	20.0

The form of the hull was assumed to be similar to that of a model tested in the NACA tank for which general test data as yet unpublished were available. This model has a transverse step, a pointed afterbody, and a length-beam ratio, excluding the tail extension, of 5.5. The lines are considered to be representative of current practice for large flying boats.

The lift and the drag coefficients of the NACA 3–10–18 wing without flaps were obtained from variable-density-tunnel data (reference 1), and the method described in reference 2 was used in calculating the lift and the drag coefficients for wings with 15° and 30° deflection of the flaps. The ground effect was calculated by conventional methods (reference 3) and was included in the computation of the effective aspect ratios (aspect ratios near the ground). The resulting lift and drag curves are shown in figures 1 and 2. The drag curves include the profile drag of the wing. Thrust data for propeller 5868–9 were obtained from propeller-research-tunnel tests (reference 4).

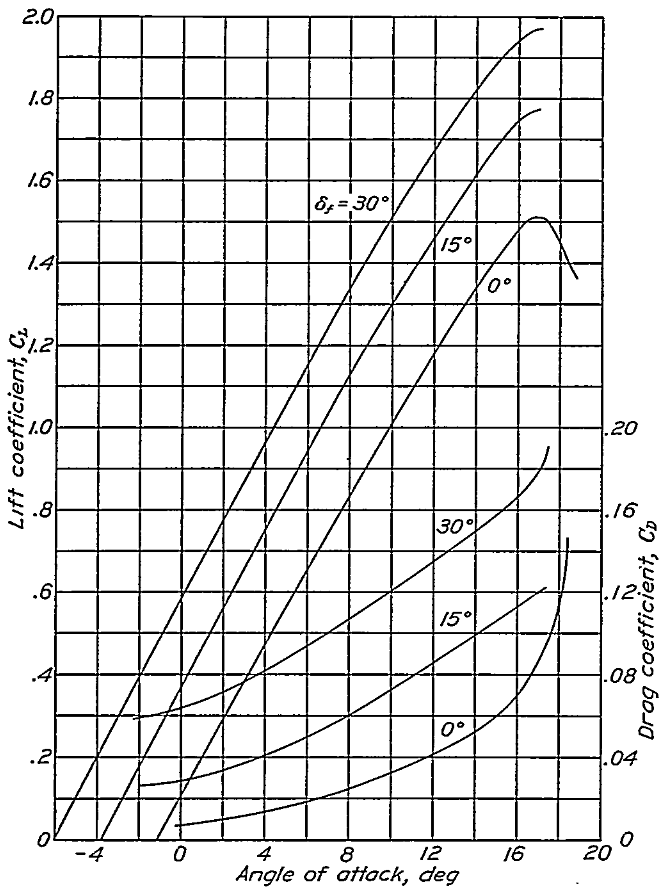


FIGURE 1.—Lift and drag coefficients of a tapered NACA 3-10-18 wing with various deflections of the flaps. A_e, 20; ground effect included.

The hull was assumed to be free to trim up to a speed below the hump speed where the trim became that for minimum water resistance (best trim). For the calculations, the assumption was made that the best trim could be maintained over the hump. Above this speed, the trim was assumed to be that for minimum water resistance, except where otherwise specified.

The total resistance $R+D$, where R is the water resistance and D is the aerodynamic drag, and the take-off performance were calculated by the methods described in reference 5. The times and the distances were, in most cases, calculated only up to the stalling speed V_s.

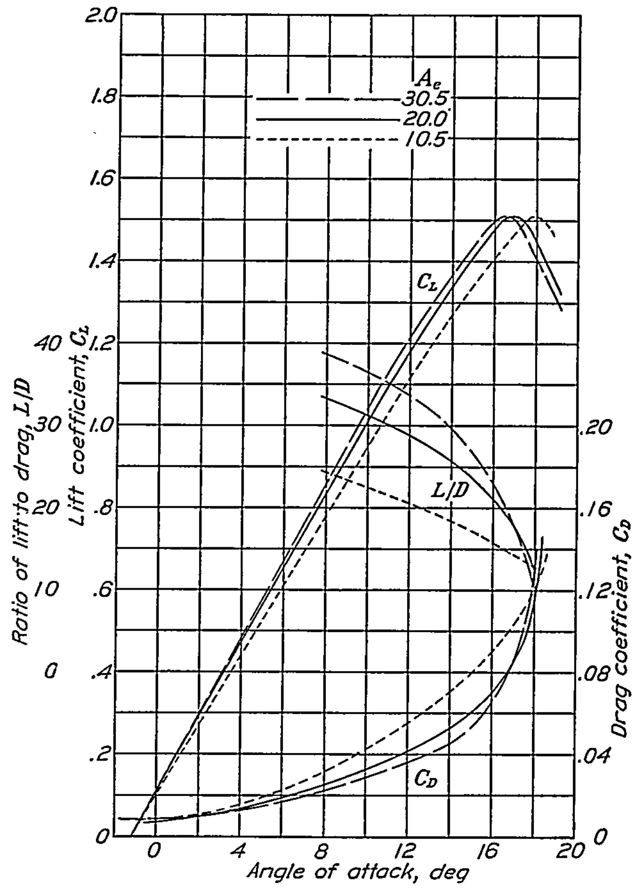


FIGURE 2.—Lift and drag coefficients of a tapered NACA 3-10-18 wing with various aspect ratios. δ_f, 0°; ground effect included.

A	A_e	Height wing/span
6	10.5	0.116
10	20.0	.090
14	30.5	.076

Because piloting technique beyond the stalling speed varies greatly, performance above the stalling speed was separately treated in several cases to find the trims for least total resistance at these speeds and hence the proper procedure for "pull-offs" to obtain best over-all take-off performance. For those cases, the method of obtaining time and distance described in reference 6 was introduced to show graphically the effect of changes in accelerating force on time and distance.

The arbitrary variations in factors, the figure numbers for the plotted results, and the calculated variations in take-off performance are summarized in table I.

TABLE I.—SUMMARY OF CALCULATIONS

Factor considered	Assumptions							Results			
	Load coefficient, C_{Δ_0}	Wing setting, i_w (deg)	Parasite-drag coefficient excluding hull, C_{D_p}	Wing loading, W/S (lb/sq ft)	Effective aspect ratio, A_e	Flap deflection, δ_f (deg)	Departure from best trim (deg)	Figure number	Time to stalling speed (sec)	Distance to stalling speed (ft)	Stalling speed (fps)
Load coefficient, with and without flaps.	0.50 .78 1.10	5	0.01	25	20	0	0	3 (a)	50.5 51.5 60.5	3,700 3,500 3,800	118
	.50 .78 1.10	5	.01	25	20	30	0	3 (b)	43.0 44.5 52.0	2,800 2,750 3,050	104
Wing setting, with and without flaps.	0.78	5 9	0.01	25	20	0	0	5 (a)	51.5 46.5	3,500 3,050	118
	.78	5 9	.01	25	20	30	0	5 (b)	44.5 44.5	2,750 2,750	104
Departure from best trim, with and without flaps.	0.78	5	0.01	25	20	0	0 1½ above 3 above 1½ below 3 below 7 fixed trim	7 (a)	51.5 56.5 105.0 67.5 (1) 51.5	3,500 3,800 6,650 4,600 (1) 3,500	118
	.78	5	.01	25	20	30	0 1½ above 3 above 1½ below 3 below	7 (b)	44.5 48.5 72.0 53.0 (1)	2,750 2,950 4,450 3,300 (1)	104
Flap deflection at 2 wing loadings.	0.78	5	0.01	25	20	0 15 30	0	11 (a)	51.5 45.0 44.5	3,500 2,850 2,750	118 109 104
	.78	5	.01	35	20	0 15 30	0	11 (b)	89.5 77.5 77.0	7,850 6,300 6,050	140 129 123
Wing loading.	0.78	5	0.01	25 35 40	20	30	0	13	44.5 77.0 [2] 100.0	2,750 6,050 [2] 8,000	104 123 131
Aspect ratio at 2 wing settings.	0.78	5	0.01	25	10.5 20 30.5	0	0	14 (a)	54.5 51.5 49.0	3,800 3,500 3,300	118
	.78	9	.01	25	10.5 20 30.5	0	0	14 (b)	53.0 46.5 45.5	3,600 3,050 2,950	118
Parasite drag, with and without flaps.	0.78	5	0.01 .02 .03 .04	25	20	0	0	15 (a)	51.5 53.5 56.0 60.5	3,500 3,700 3,950 4,350	118
	.78	5	.01 .02 .03 .04	25	20	30	0	15 (b)	44.5 46.5 48.5 51.0	2,750 2,900 3,050 3,250	118

[1] No take-off.
[2] Approximate value.

In table I, the load coefficient is that used at the NACA tank to express the ratio of gross load to size of hull for a given form of hull and is defined as follows:

$$\text{Load coefficient, } C_{\Delta_0}=\frac{\Delta_0}{wb^3}$$

where

Δ_0 gross load, pounds.

w specific weight of water, pounds per cubic foot.

b maximum beam of hull, feet.

The remaining factors are defined as follows:

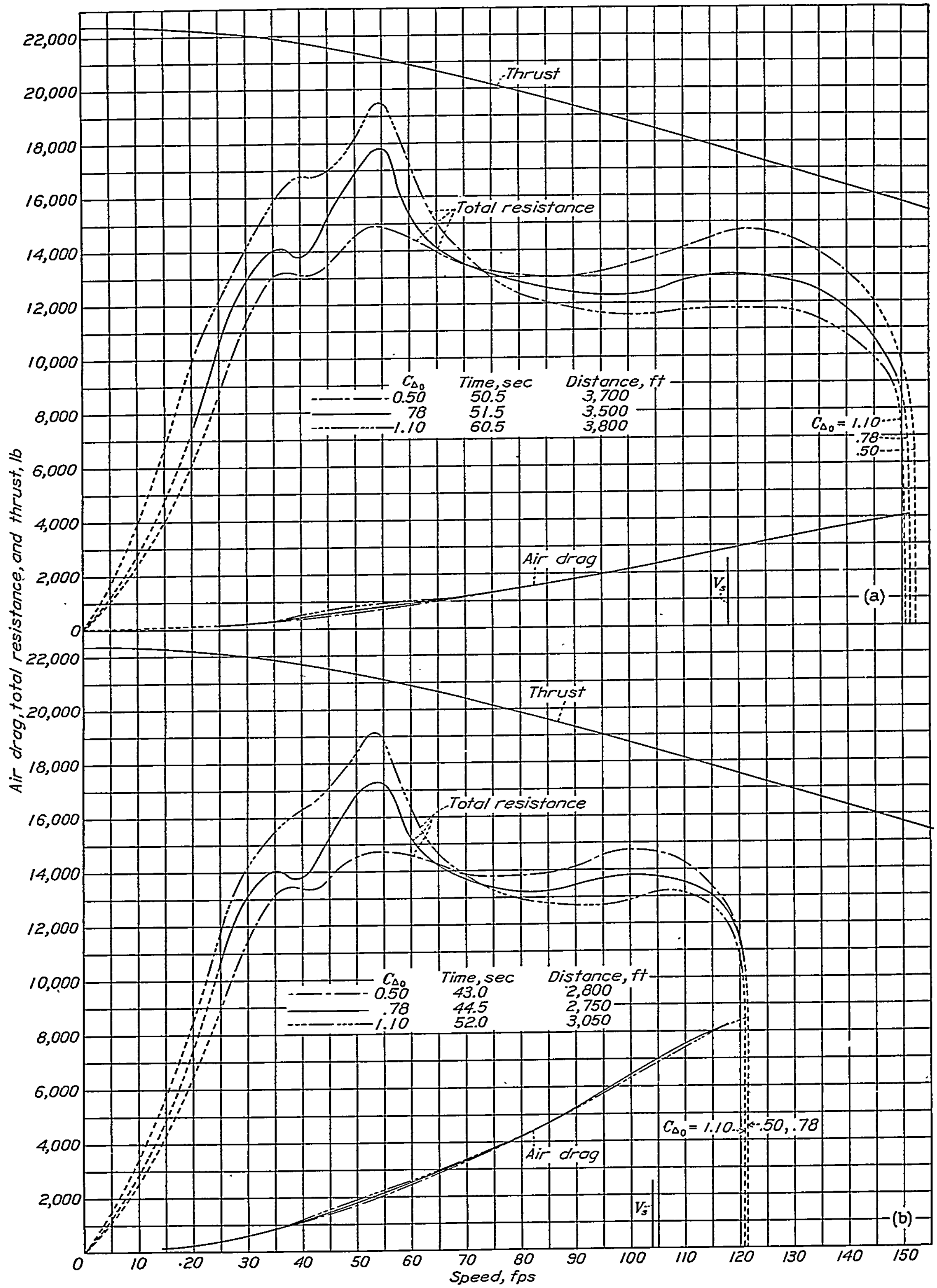
i_w wing setting, degrees, from base line of hull.

C_{D_p} parasite-drag coefficient, based on wing area and excluding drag of hull.

W/S wing loading, pounds per square foot.

A_e effective aspect ratio including ground effect.

δ_f deflection of flap, degrees from wing chord.



(a) $\delta_f=0°$.
(b) $\delta_f=30°$.

FIGURE 3.—Effect of load coefficient, C_{Δ_0}, on take-off. i_w, 5°; C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20.

DISCUSSION OF RESULTS

Load coefficient.—Figure 3 (a) shows a comparison of the total-resistance curves with three load coefficients applied to the same hull lines, with the flaps at 0°. The largest load coefficient, 1.10, corresponding to the smallest size of hull, is considered to have too high hump resistance. The time and the distance to stalling speed, with load coefficients of 0.50 and 0.78, vary but little. With the lighter loading (larger hull), the time is slightly less and the distance is slightly greater. Because of the small difference in performance for large differences in load coefficient, it is apparent that, for this example, the size of hull would probably be determined by other considerations such as spray characteristics, structural weight, or drag in flight.

The same load coefficients were investigated with the flaps deflected 30° (fig. 3 (b)). The relative effect on the take-off performance produced by the variations in load coefficient was unchanged by the addition of the flaps.

A load coefficient of $C_{\Delta_0}=0.78$ gives a size of hull in which the mean excess thrust at the hump is approximately equal to that at high speeds. Since this characteristic is considered desirable, a value of the load coefficient C_{Δ_0} of 0.78 was used for the rest of the investigation.

Wing setting.—For optimum performance, it would be desirable to vary the wing setting continuously with speed. Inasmuch as it is impracticable to vary the wing setting continuously, a compromise fixed setting of the wing must be chosen that will result in satisfactory take-off performance. The wing setting is important because it influences the load on the water and the wing drag. Previous work on older designs of rather low aspect ratio (reference 7) has indicated that, if the wing setting is selected for minimum total resistance at about 85 percent of the stalling speed and if trim for minimum water resistance is held throughout the take-off run, the take-off time and distance are about the optimum. Figure 4 indicates that this arbitrary method of selecting the wing setting is satisfactory for the present example.

In a flying boat with wings of high aspect ratio, the increase in induced drag with an increase of angle of attack is small; the lift-drag ratio at large angles of attack (fig. 2) is such that it becomes profitable to increase the unloading for a given speed and trim by increasing the wing setting. The optimum wing setting in this case is too large to be practicable; if it were used, the wings would be in the stalled attitude at around hump speed although the hull would be at the trim corresponding to minimum water resistance. Also, in flight, the angle of the hull would be below the angle for minimum aerodynamic resistance. The wing setting must therefore be made less than that needed for optimum water performance.

For these reasons, 5° was assumed for the angle of wing setting for the first part of the investigation; whereas, 9° would have given lower total resistance over practically the entire take-off range. An angle of wing setting of 9° was tried, however, in the investigation of the effect of aspect ratio because a high angle of wing setting was known to accentuate the effect of changes in aspect ratio.

Figure 5 (a) shows the effect of angle of wing setting with flaps retracted; figure 5 (b) shows the effect with flaps deflected 30°. A comparison of the two figures shows that, when flaps are used, the beneficial effect of the higher wing setting is negligible. A comparison of figures 6 (a) and 6 (b) shows that a change in angle of wing setting from 5° to 9° is almost as effective in

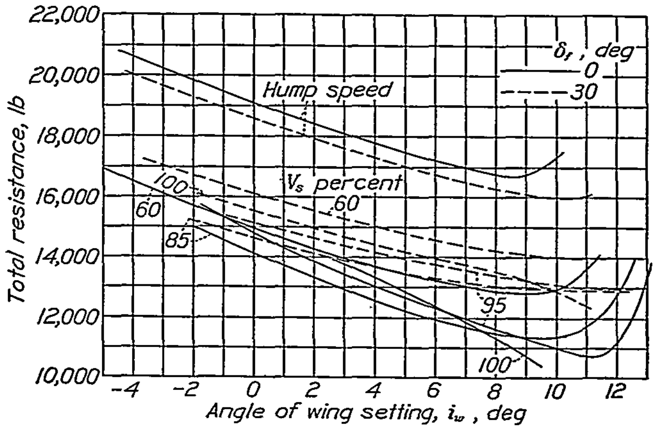
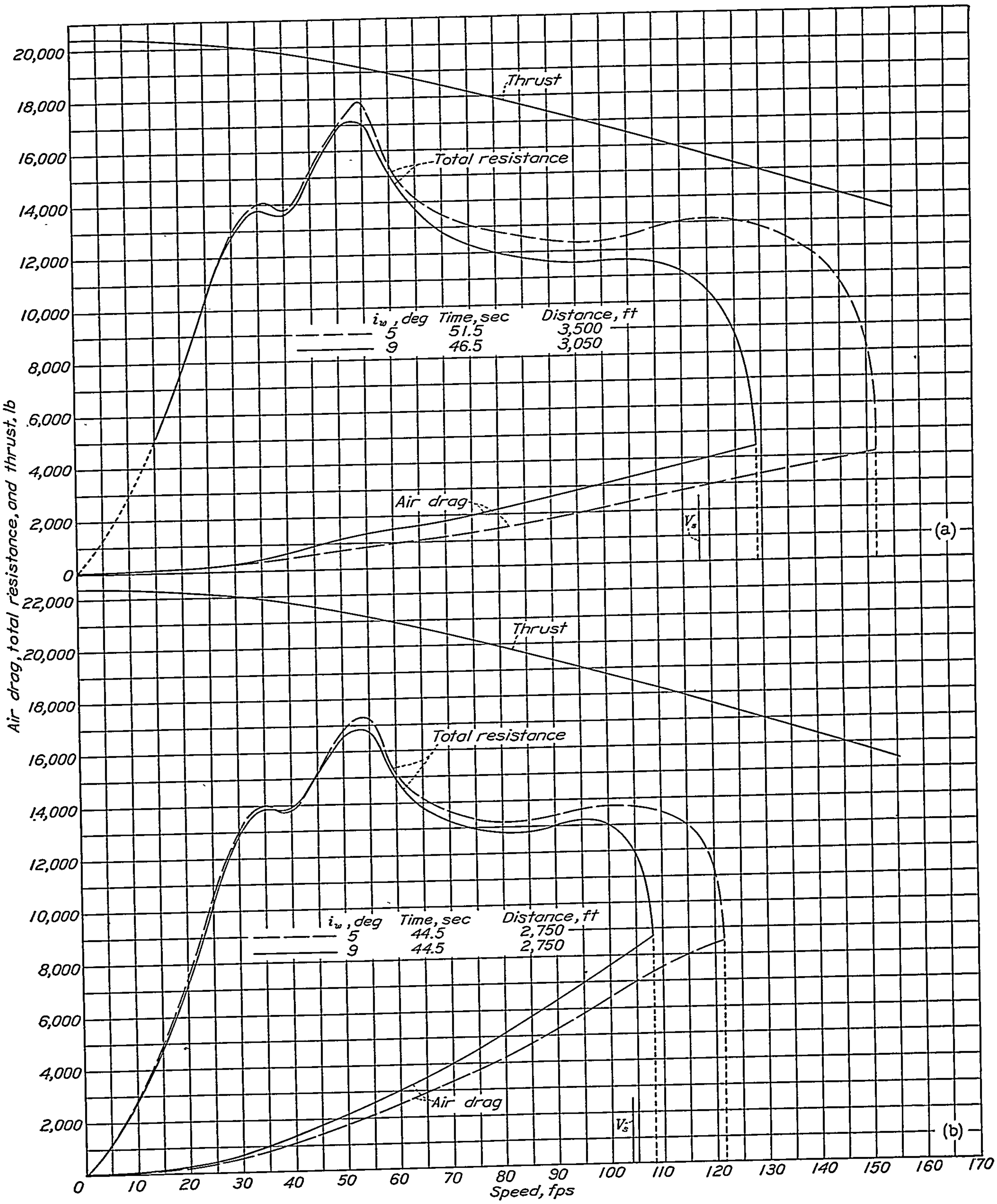


FIGURE 4.—Variation of total resistance with angle of wing setting. C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20; C_{Δ_0}, 0.78.

unloading the hull as a change in deflection of the flap from 0° to 30°.

Trim.—The trim of the hull is one of the most important variables affecting the take-off performance of a seaplane. Resistance increases appreciably with departure from the trim corresponding to minimum water resistance. Hulls usually trim too high at the hump, where the elevator control is somewhat ineffective.

Figure 7 (a) shows the resistance curves of the hypothetical flying boat, during a take-off, following the trim for minimum water resistance and the trims 1½° and 3° above and below this trim, with flaps set at 0°. The time and the distance to stalling speed are increased by about 90 percent if the trim is 3° greater than the trim for minimum water resistance. The treatment of the speed range above stalling speed is discussed later. In the take-off it is more desirable to be above rather than below the trim for minimum water resistance because "trimming up" produces an additional increment of aerodynamic lift, thereby lightening the load on the water. (See fig. 6 (c).) This effect offsets to a certain extent the increase in water resistance accompanying the higher trim. A take-off, if 3° below the trim for minimum water resistance were kept, would be impossible. Reference 7 shows a similar effect of trim on a smaller flying boat, with hydrodynamic and aero-



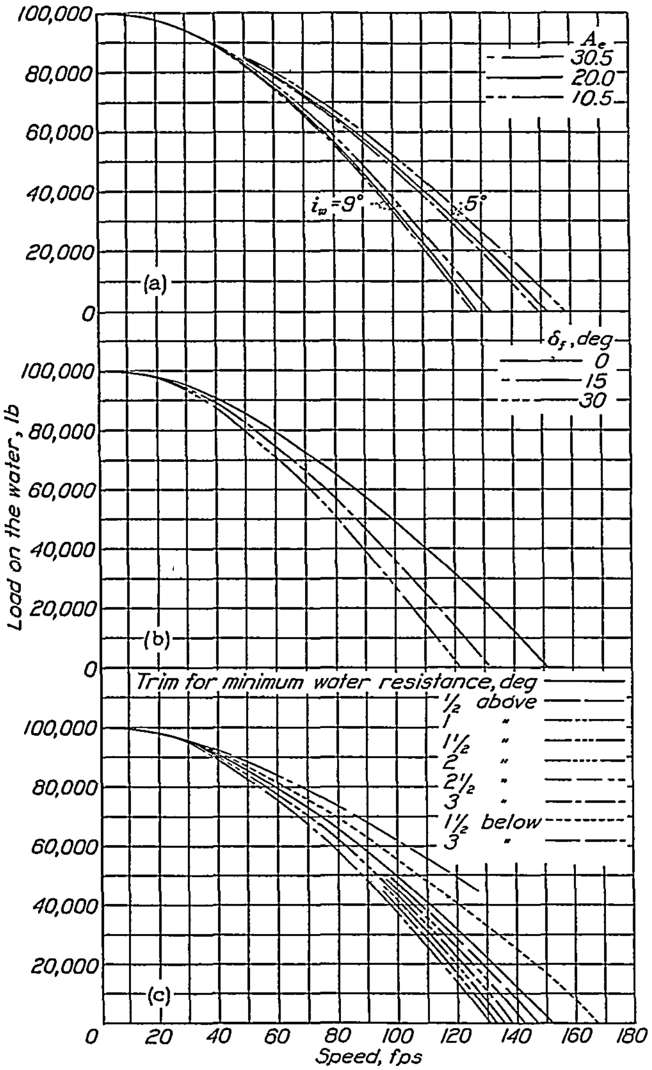
(a) $\delta_f=0°$.
(b) $\delta_f=30°$.

FIGURE 5.—Effect of wing setting, i_w, on take-off. C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20; C_{A_0}, 0.78.

dynamic characteristics quite different from the one under consideration.

The use of flaps does not greatly affect the magnitude of the increase in resistance at a given speed produced by a trim different from the trim for minimum water resistance (see fig. 7 (b)), but the percentage increase is reduced because the total resistance has been increased by the additional drag of the flaps.

A study of the curves in figure 8, which show the effect of trim on total resistance, indicates that, when the angle of wing setting is lower than the optimum, the total resistance may be decreased by using a trim greater than that for minimum water resistance. At ½° or 1° above the trim for minimum water resistance, the total resistance, beginning at about 72 feet per second, is lower. The saving is small but definite up to the take-off speed. Too high a trim may increase the total resistance to such an extent that the excess thrust may be insufficient to take the boat off the water.



(a) Effect of i_w and A_e on unloading of hull. δ_f, 0°.
(b) Effect of δ_f on unloading of hull. A_e, 20.
(c) Effect of trim on unloading of hull. δ_f, 0°; A_e, 20.

FIGURE 6.—Effect of various factors on unloading of hull. C_{D_p}, 0.01; W/S, 25 pounds per square foot; C_{Δ_0}, 0.78.

In figure 8, the lines drawn between the curves of total resistance and thrust have a slope of $\frac{\Delta_0}{32.2 \text{ ft/sec}}$. The time in seconds is given by the number of intercepts of the lines with the total-resistance ($R+D$) and the thrust curves, and the distance is the sum of the speeds at each second or intercept (reference 6).

When the excess thrust near take-off is small, the importance of operating at the precise trim, or trims, that will give the minimum total resistance is accentuated. Figure 8 illustrates a method of determining the schedule of trims to be followed for a precision take-off, that is, a take-off in which the hull is kept at an attitude giving the minimum total resistance. The lower envelope of the resistance curves in figure 8 gives the optimum performance if the corresponding trims are maintained. This method of determining precision trim can be applied to any design for which aerodynamic and hydrodynamic performance data are available. Time may be saved by computing the total resistance ($R+D$) for several fixed trims of the hull and using the envelopes of these curves as suggested in reference 8.

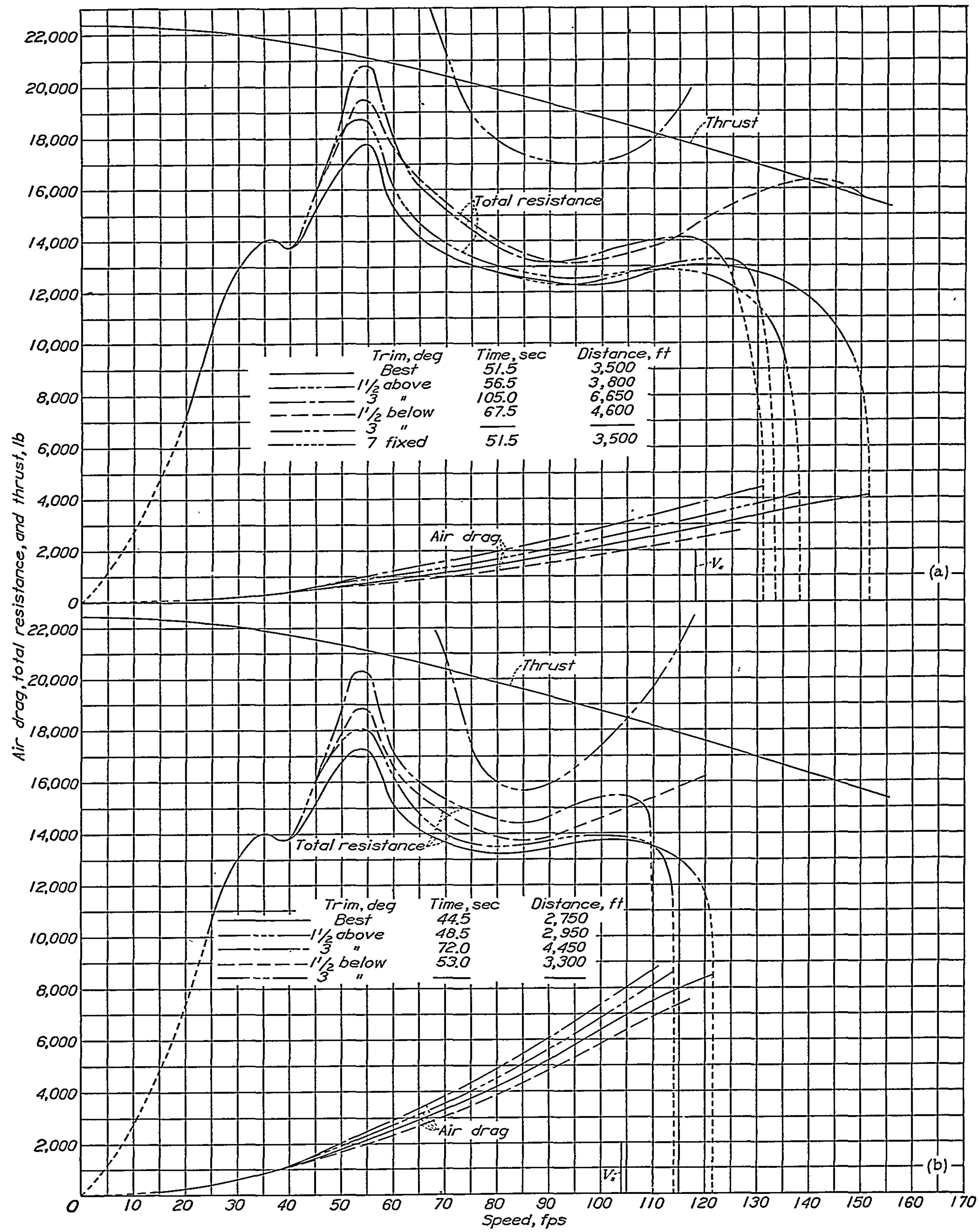
In figure 9 are shown the curve of trims for minimum water resistance in the high-speed range, as obtained by computation, and also the similar curve of trims, derived from figure 8, for precision take-off (optimum performance). The derived curve lies close to a trim of 7° for practically its entire length; it therefore appears that a constant trim of 7° through the high-speed range might be used as a substitute.

When the three schedules of trims of figure 9 were considered in turn, it was found that, by following the trim for minimum water resistance to fly-off, the time is 77 seconds and the distance is 6,900 feet. If the precision trim is followed exactly to take-off, the time is 61 seconds and the distance is 4,700 feet. When the trim is held constant at 7° to fly-off, the time is 63 seconds and the distance is 4,900 feet. The time and distance data for these conditions of take-off are given in table II. The close agreement between the last two times and distances indicates that holding a fixed trim of 7° at high speeds results in very nearly the optimum performance.

TABLE II.—TIME AND DISTANCE TO TAKE-OFF

[C_{Δ_0}=0.78; i_w=5°; C_{D_p}=0.01; W/S=25 lb/sq ft; A_e=20]

Condition of take-off	Time (sec)	Distance (ft)
Best trim	77	6,900
Precision trim	61	4,700
7° fixed trim during high-speed portion	63	4,900
Delayed action of flaps	52	3,700



(a) $\delta_f=0°$.
(b) $\delta_f=30°$.

FIGURE 7.—Effect of trim on take-off. i_w, 5°; C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20; $C\Delta_0$, 0.78.

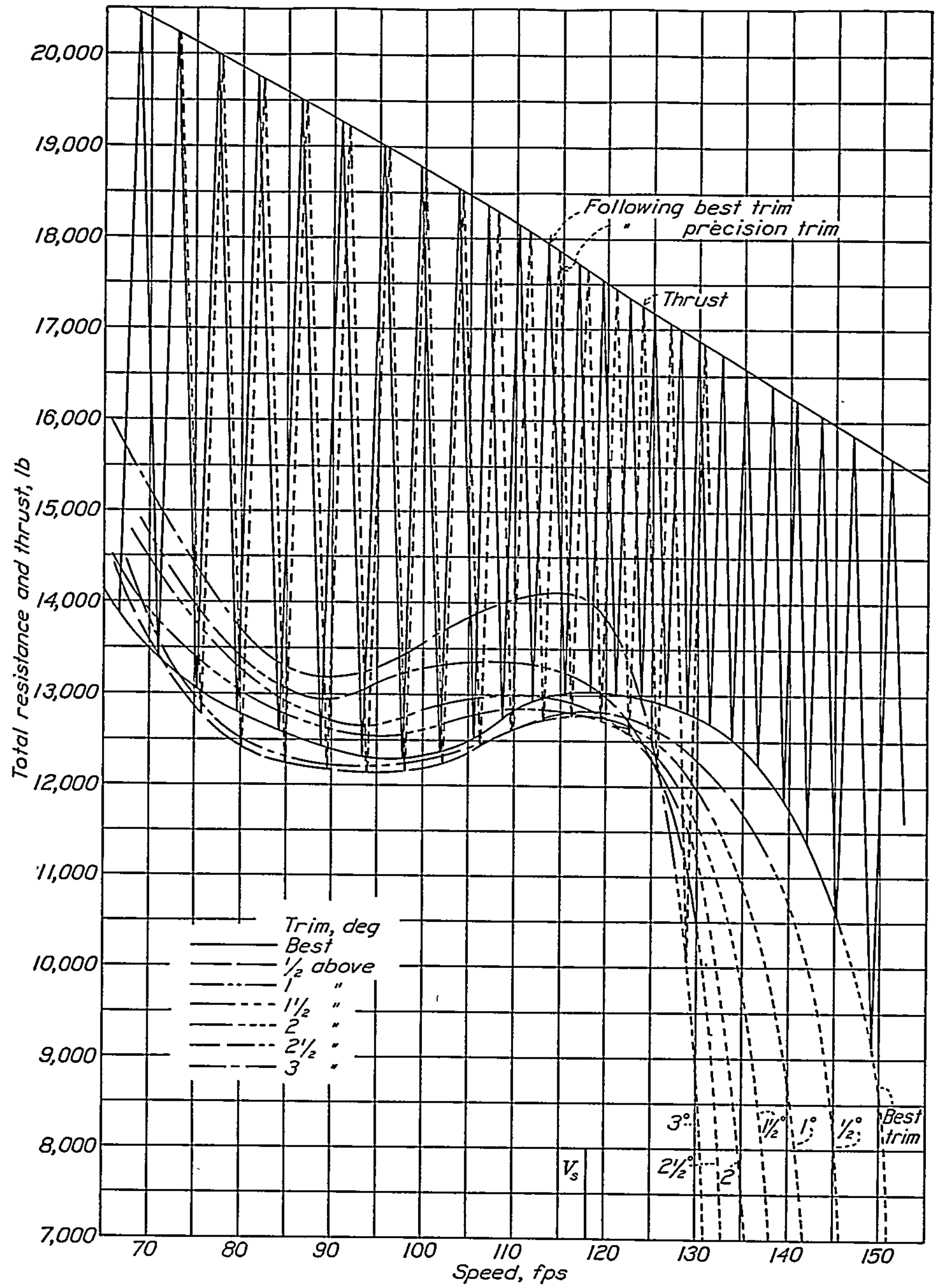


FIGURE 8.—Effect of trim at high speeds. δ_f, 0°; i_w, 5°; C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20; C_{Δ_0}, 0.78.

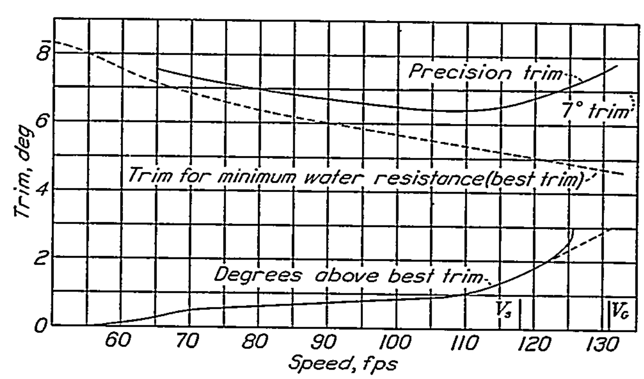


FIGURE 9.—Trim schedule at high speeds for a precision take-off. δ_f, 0°; i_w, 5°; C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20; C_{Δ_0}, 0.78.

Figure 10 shows the effect of increasing the trim near take-off. In this figure, the trim is assumed to change at the rate of 1.5° per second beginning at 118 feet per second, the stalling speed. A sharp peak occurs in the total-resistance curve which, in some cases, might be sufficiently high to prevent take-off.

Deflection of flaps.—The effect on take-off of several constant deflections of the flaps is shown in figure 11 (a) for a wing loading of 25 pounds per square foot and a load coefficient of 0.78. With the 15° deflection, the total resistance is slightly greater than for 0° deflection but the take-off occurs at a lower speed because of the faster unloading. Increasing the deflection of the flaps to 30° increases the total resistance by a larger percentage in the planing region and reduces the take-off by a smaller percentage. The advantage of the faster unloading is decreased because of the greater aerodynamic drag with a 30° deflection. The time and the distances to the stalling speed are about the same with the flaps deflected 15° or 30°. The take-off examples of reference 9, for a smaller hypothetical flying boat, show the same trends.

Figure 11 (b) shows the effect of flaps for a wing loading of 35 pounds per square foot and illustrates the increased importance of flaps for the purpose of increasing the lift and decreasing the load on the water when the wing loading is increased.

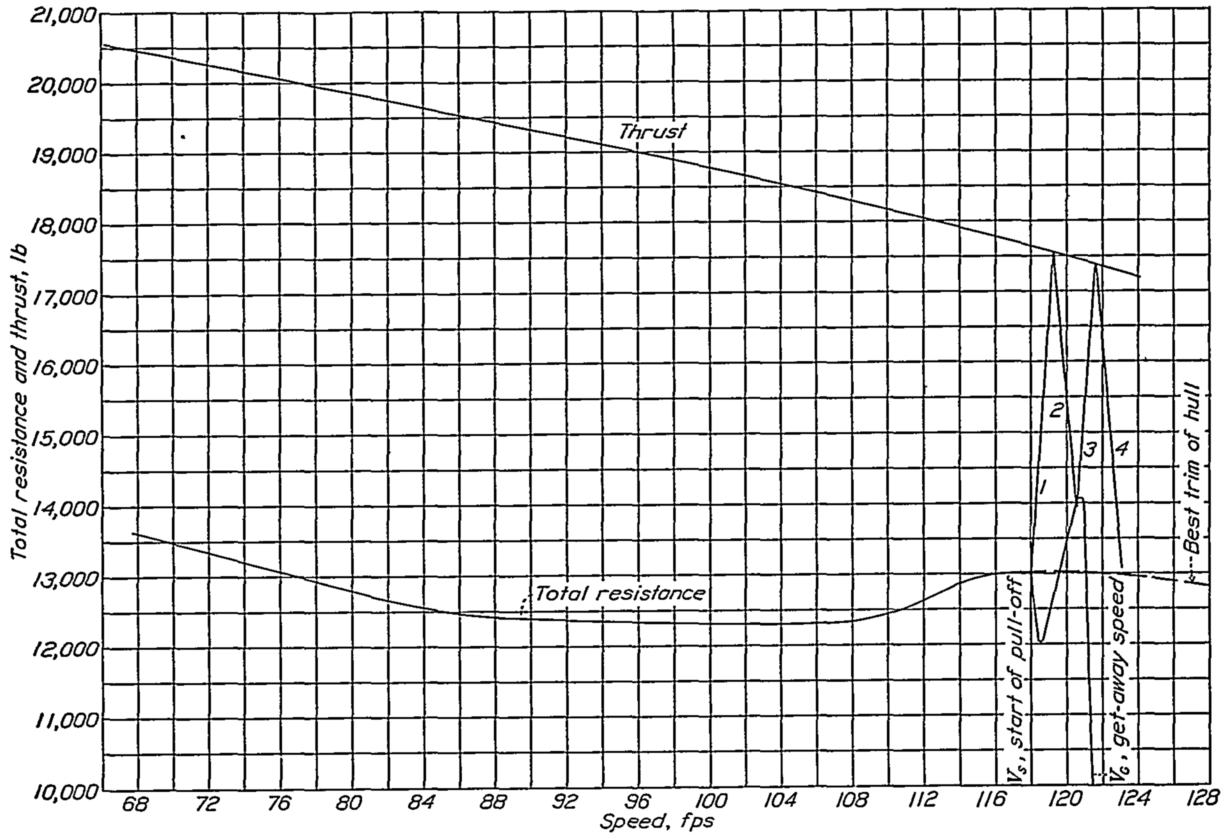
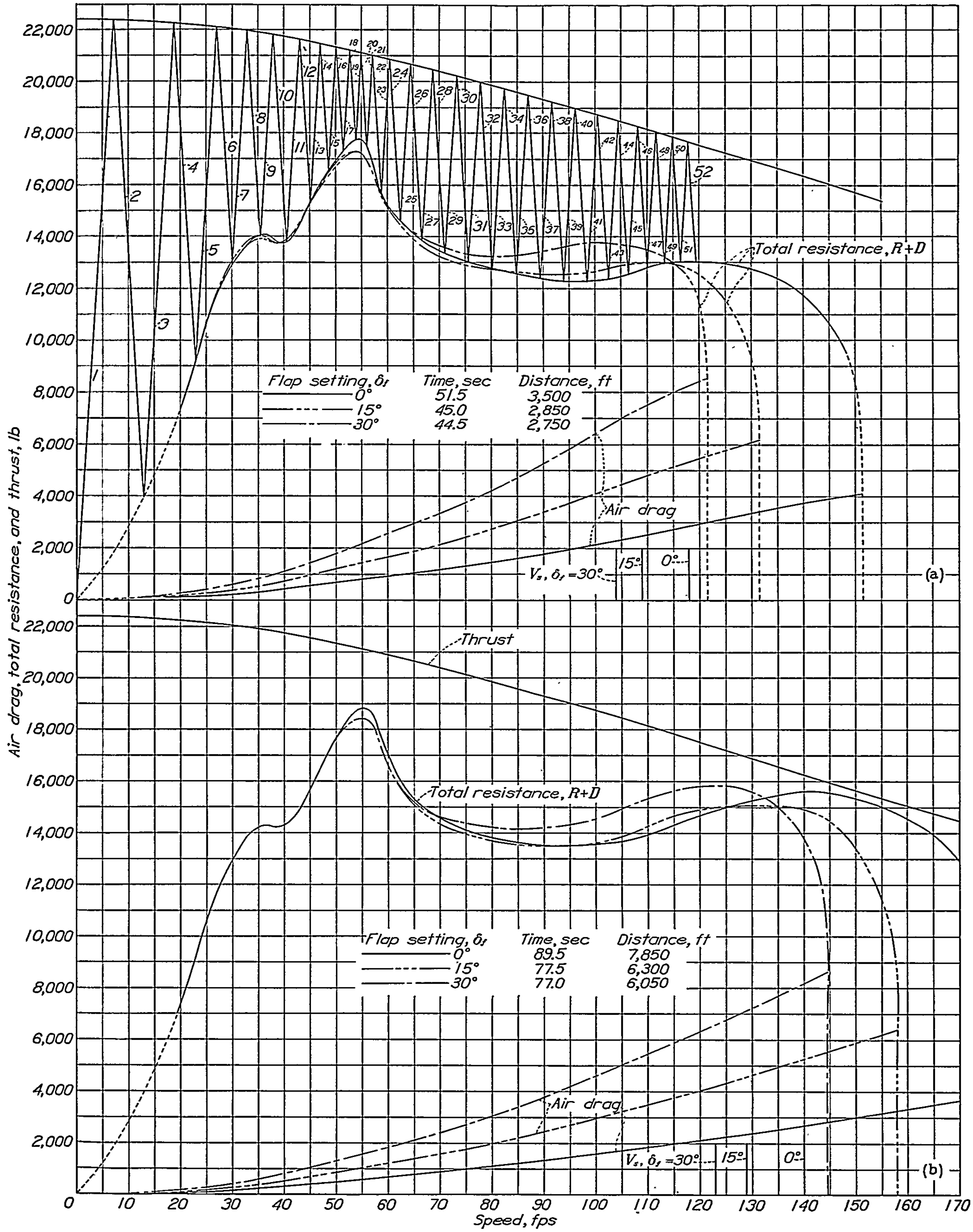


FIGURE 10.—Effect of pulling up at a rate of 1½° per second. δ_f, 0°; i_w, 5°; C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20; C_{Δ_0}, 0.78.

A study of the resistance curves, several constant deflections of the flaps being used, suggests that take-off could be improved by deflecting the flaps just prior to reaching stalling speed. By a deflection of the flaps just prior to stall, advantage can be taken of the lower stalling speed without paying the penalty of increased resistance during the earlier part of the take-off. Upon investigation, it was found that flaps of existing large four-engine airplanes of late design could be deflected from 0° to 30° in about 5 seconds.

Figure 12 shows the theoretical gain in take-off performance made possible by delayed deflection of the flaps. The scale of the figure is chosen to give an enlarged view of the high-speed portions of the total-resistance curves in figure 11 (a). It is assumed that the flaps are kept at 0° up to a speed of about 80 feet per second, which is attained 32 seconds after the start, and that the flaps are then deflected at the rate of 30° in 20 seconds or 1½° per second. The dashed line (fig. 12) represents the resulting resistance and was obtained by successive approximations. The take-off then requires a time of 52 seconds and a distance of 3,700 feet. This take-off may be compared with a precision take-off without flaps (see table II); the time is decreased by about 15 percent and the distance is decreased by about 25 percent when the delayed action of the flaps is used.



(a) W/S=25 pounds per square foot.
(b) W/S=35 pounds per square foot.

FIGURE 11.—Effect of flaps on take-off. i_w, 5°; C_{D_p}, 0.01; A_e, 20; C_{Δ_0}, 0.78.

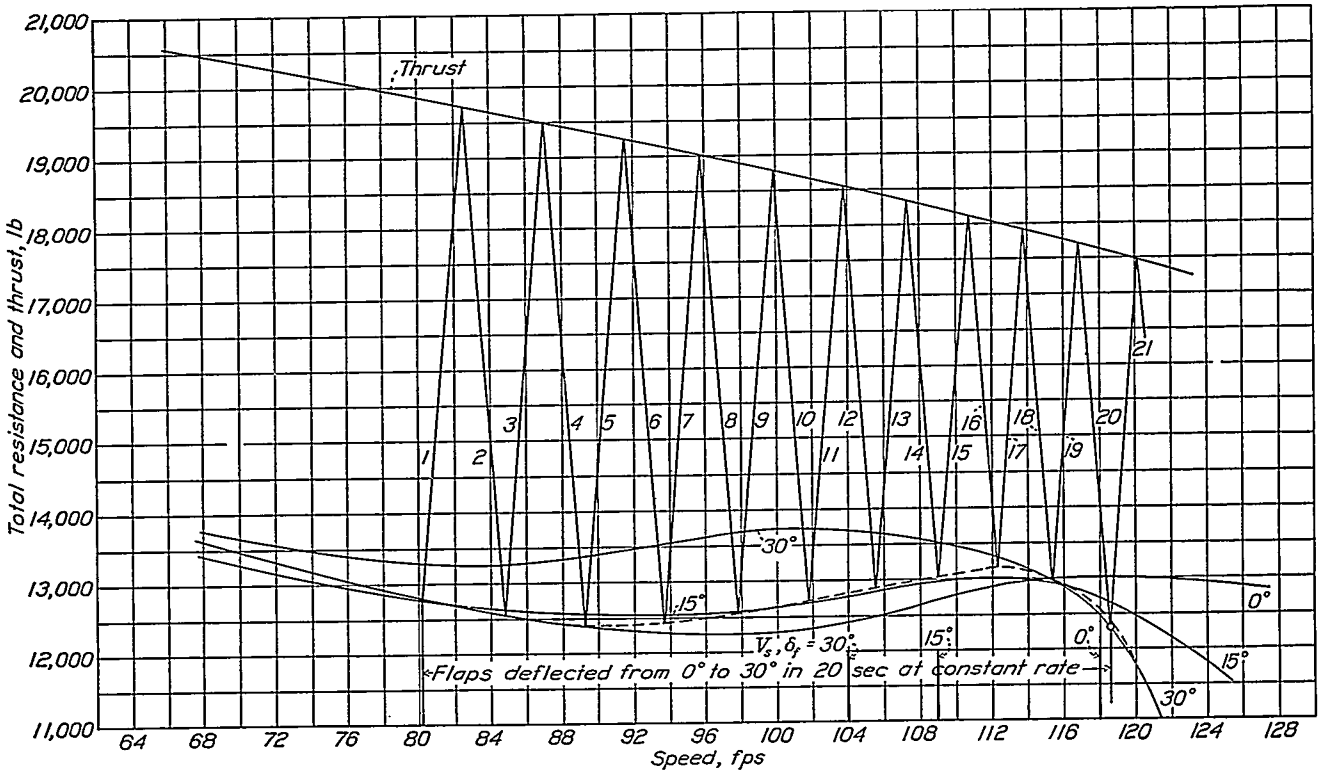


FIGURE 12.—Pull-off, deflecting flap while keeping hull at best trim. i_w, 5°; C_{D_p}, 0.01; W/S, 25 pounds per square foot; A_e, 20; C_{Δ_0}, 0.78.

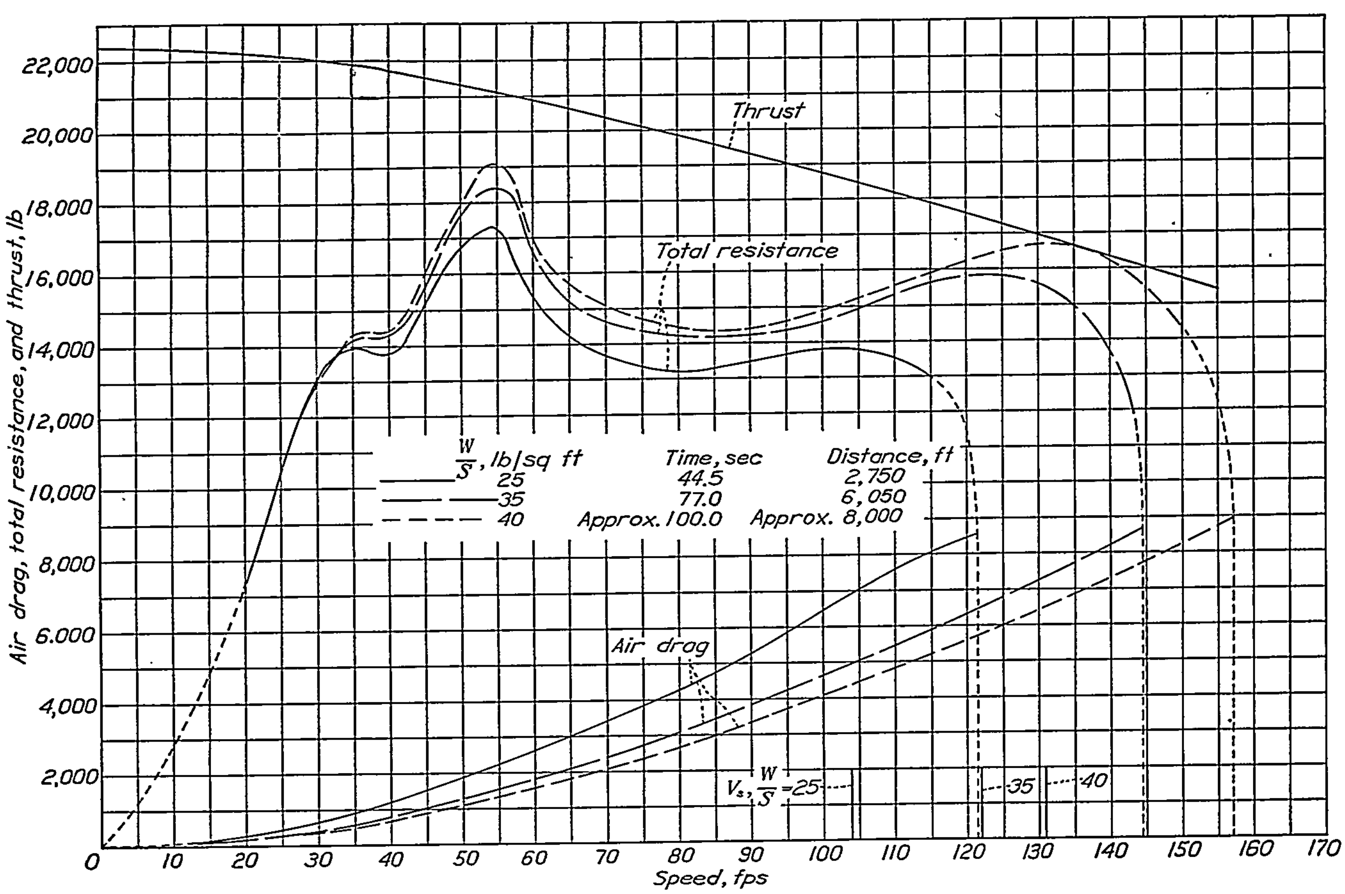
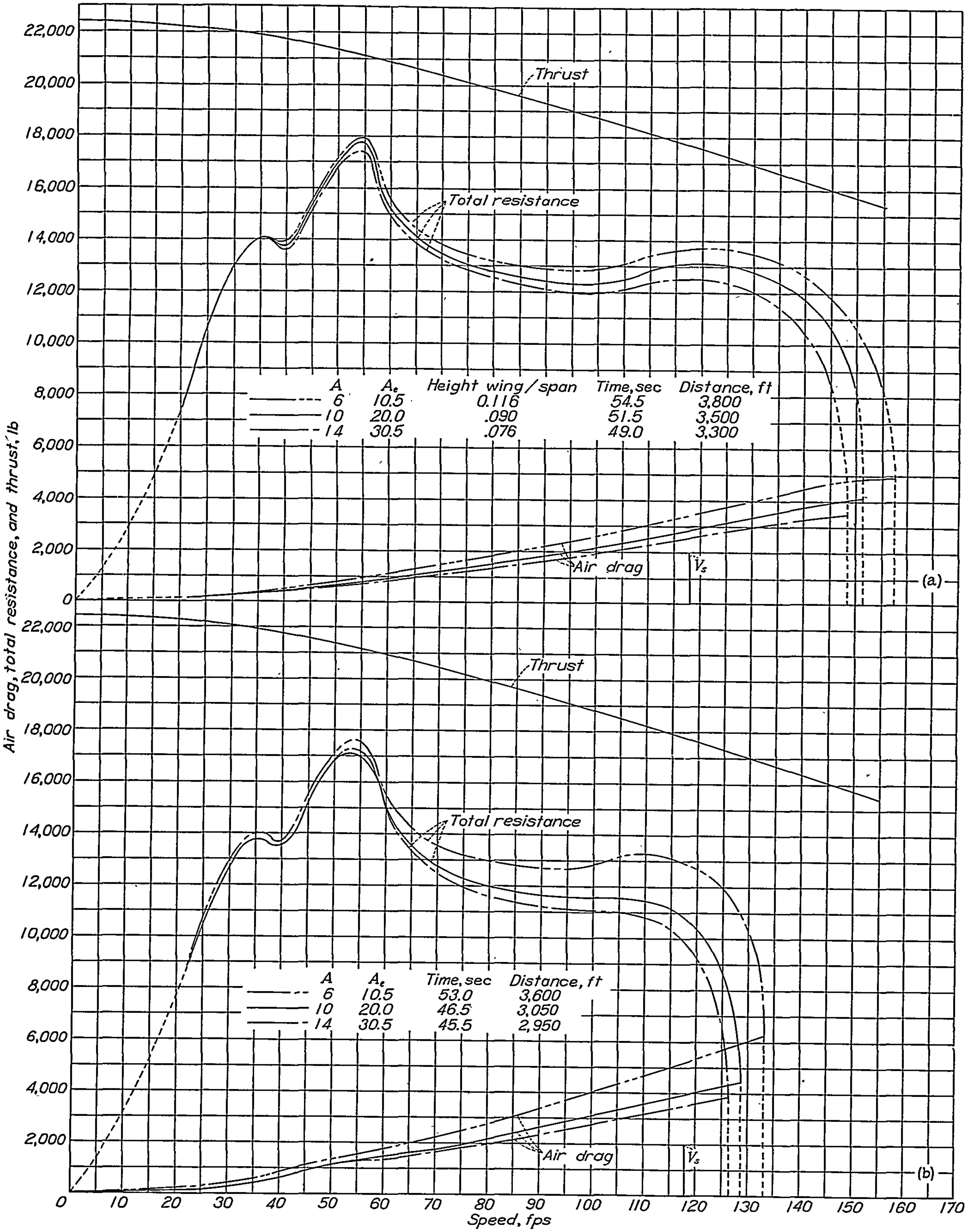
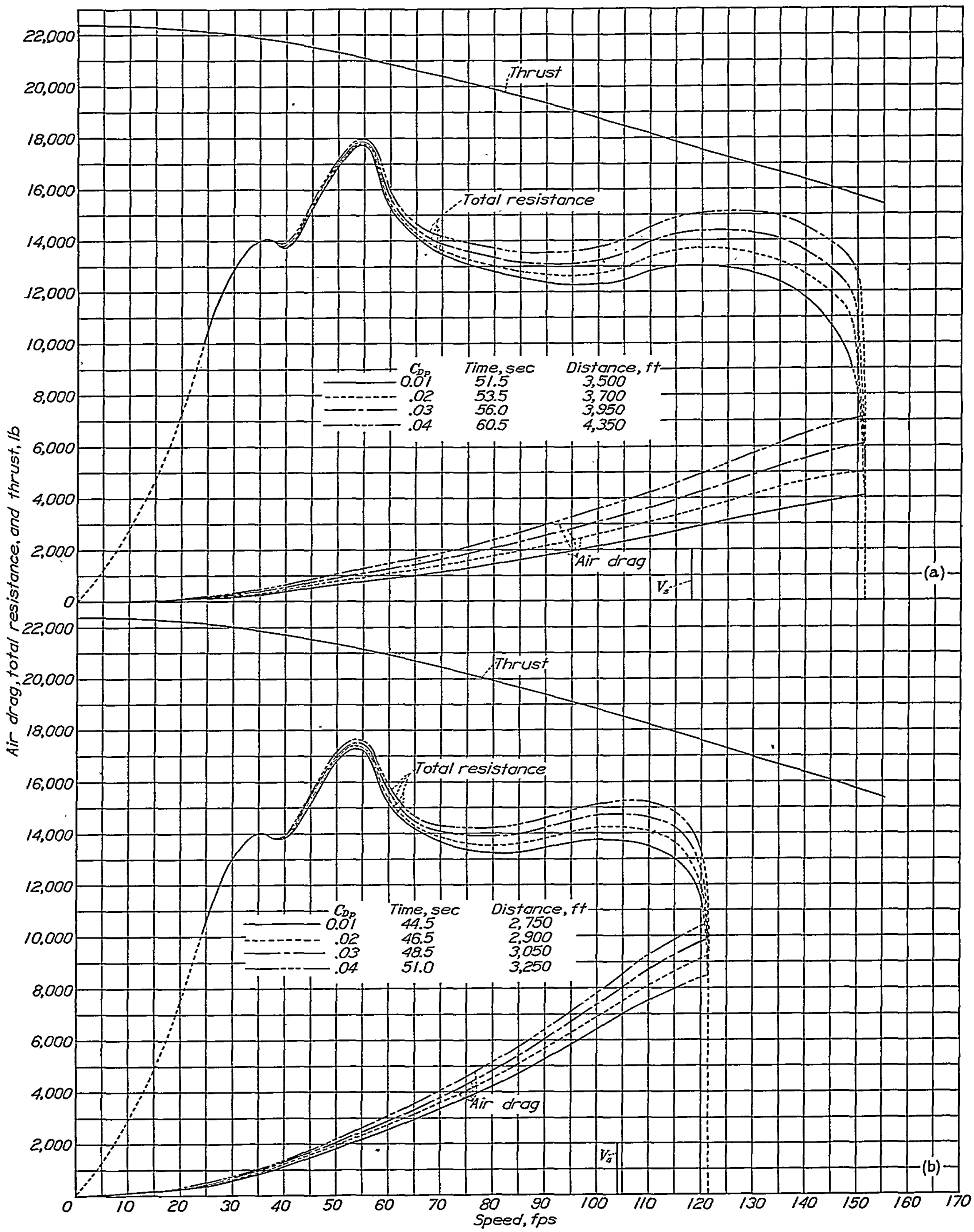


FIGURE 13.—Effect of wing loading on take-off. δ_f, 30°; i_w, 5°; C_{D_p}, 0.01; A_e, 20°; C_{Δ_0}, 0.78.



(a) $i_w=5°$.
(b) $i_w=9°$.

FIGURE 14.—Ground effect, using various spans at a constant height above the water (18 ft). δ_f, 0°; C_{D_p}, 0.01; W/S, 25 pounds per square foot; C_{L_0}, 0.78.



(a) $\delta_f=0°$.
(b) $\delta_f=30°$.

FIGURE 15.—Effect of parasite-drag coefficient, C_{D_p}, on take-off. i_w, 5°; W/S, 25 pounds per square foot; A_e, 20; C_{L_0}, 0.78.

Wing loading.—A wing loading of 25 pounds per square foot was assumed for most of the investigations because it permitted enough excess thrust for take-off in a reasonable distance and time with variations used that considerably increased the total resistance. Existing designs of 100,000-pound flying boats have wing loadings of 30 pounds per square foot or more; the use of flaps for taking off and landing is contemplated. In order to make the present investigation cover the trend toward greater wing loadings with increase in size, a wing loading of 35 pounds per square foot was investigated in connection with deflection of the flaps. Increasing the wing loading normally increases the parasite drag coefficient. This change is small, however, and was neglected in this investigation. A study of figure 11 will show that the high-speed resistance is appreciably increased by the higher wing loading; moreover, the thrust curve has dropped until the excess thrust is small. The use of flaps before the stalling speed is reached would seriously reduce the amount of excess thrust. If no flaps are used, the get-away occurs at such a high speed that the curve of total resistance almost touches the thrust curve.

Figure 13 shows the variation in total resistance for three conditions of wing loading, 25, 35, and 40 pounds per square foot, with flaps deflected 30°. With the wing loading of 40 pounds per square foot, a take-off following trim for minimum water resistance would be impossible because at a speed only slightly above the stalling speed the total resistance is equal to the available thrust. Although the aerodynamic drag, for a given speed, is decreased with an increase in wing loading, the total resistance is greater. This result is to be expected since the load on the water is also increased because of the reduced lift of the smaller wing. As the wing loadings become greater, more emphasis will be placed on the importance of low water resistance at high speeds. Methods of assisting the unloading of the hull, such as higher angles of wing setting and the use of more efficient flaps, will offset to a certain extent the effect of the increased resistance at high speeds for the higher wing loadings.

Aspect ratio.—Figure 14 (a) shows the effect of varying the assumed geometrical aspect ratio while the wing is at a constant height (18 ft) above the water. The flaps were not deflected and the angle of wing setting was 5°. At high speeds, the larger aspect ratios give a small but definite improvement.

Figure 14 (b) shows the increased importance of aspect ratio when an angle of wing setting of 9° is used. The reason for this added importance is that the greatest divergence in the drag curves of the various aspect ratios (see fig. 2) occurs at angles of attack above 12°, where the lift and the induced drag become appreciable. The same reasoning applies to the use of high aspect ratios with deflected flaps. The lift coefficient becomes much higher, induced drag is increased, and the beneficial effect of higher aspect ratios in reducing the induced drag is therefore increased.

Higher aspect ratios increase the optimum angle of wing setting but, unless hulls are specifically designed to have low air drag when cruising with the hull down by the bow, the higher wing settings could not profitably be used.

Parasite drag.—Figure 15 (a) shows the effect of parasite drag, without the use of flaps. Parasite drag becomes important at and above stalling speed. In this high-speed range, the thrust curve may have dropped sufficiently to make the magnitude of the parasite drag an important factor in the performance.

When the flaps are deflected 30° (fig. 15 (b)), the drag of the wings is increased and the parasite drag represents a smaller percentage of the total. Since the take-off speed has decreased and the available thrust at take-off is therefore greater, the resistance added by the parasite drag is less critical.

CONCLUSIONS

The following conclusions apply particularly to a design having the characteristics assumed for this investigation, but they may be useful in predicting changes in performance produced by the same variable in other designs.

1. Load coefficient:
    - a. The take-off performance is not particularly sensitive to change in load coefficient resulting from change in the size of hull for the form being considered. The upper limit in load coefficient may be determined by the magnitude of the resistance and the trim at hump speed and by the spray characteristics.
    - b. The same conclusion applies when a wing with a flap deflection of 30° is used.
2. Wing setting:
    - a. Selecting an angle of wing setting that gives a minimum total resistance at 85 percent of the stalling speed produces a good compromise setting even with present design.
    - b. With increase in aspect ratio, the angle of wing setting for optimum take-off increases and may become greater than is feasible for use.
    - c. The loss in take-off performance resulting from the use of wing settings lower than optimum is less when flaps are used.
3. Trim:
    - a. Up to the stalling speed, deviations of more than 1½° above or 1° below the trim for minimum water resistance result in large increases in total resistance and, consequently, in time and length of take-off.

b. The foregoing limits also apply when flaps are used.

c. Trims above that for minimum water resistance have less adverse effect on take-off performance than trims below that for minimum water resistance.

d. Above the stalling speed, the trim for minimum total resistance becomes greater than that for minimum water resistance. Too high a trim, however, results in a sharp increase in total resistance. The best procedure for taking off consists essentially in holding a constant trim somewhat above that for minimum water resistance rather than sharply increasing the trim near get-away speed.

4. Deflection of flaps:

a. Flaps increase the total resistance at planing speeds but decrease the get-away speed. There is little advantage in using a deflection of the flaps greater than 15°. The net effect of their use with high wing loadings is to improve take-off performance.

b. The favorable effect of the flaps increases with wing loading.

c. The best take-off performance is obtained by deflecting the flaps quickly at high speeds, thus taking advantage of the lower get-away speed without increasing the total resistance in the planing range.

5. Wing loading:

a. Increase in wing loading impairs the take-off performance and increases the importance of low water resistance at high speeds.

b. The use of flaps, large angles of wing setting, and high aspect ratio are favorable in offsetting the disadvantageous effect of high wing loading.

6. Aspect ratio:

a. Increase in aspect ratio definitely improves take-off performance. The improvement is most notable at effective aspect ratios below 20; above 20 the improvement is small.

b. The improvement is greater for high angles of wing setting than for low angles.

7. Parasite drag:

a. The effect of parasite drag is most marked at high speeds and hence is important when high wing loadings are used.

b. The use of flaps lessens the effect of parasite drag on take-off performance.

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